School Bus Restraint Study

National Highway Traffic Safety Administration

Linda McCray - OVSR/NHTSA

Lisa Sullivan - VRTC/NHTSA

Jeff Elias - TRC Inc.

BACKGROUND

- 440,000 Public School Buses
- 4.3 Billion Miles
- 23.5 Million Children to and from School

BACKGROUND

- **Last FMVSS 222 Rulemaking Efforts Occurred in 70's**
  - Passive Protection - Compartmentalization
- **1998 A Congressional Mandate to Evaluate Next Generation School Bus Safety Restraints**

CURRENT FMVSS 222
School Bus Seating and Crash Protection

- **For School Buses Greater than 10,000 pounds GVWR**

Passenger Occupant Protection (compartmentalization) - Requires that the interior of large school buses provide occupant protection so that children are protected without the need to buckle-up

CURRENT FMVSS 222
School Bus Seating and Crash Protection

- **School Buses Equal to or Less Than 10,000 Pounds GVWR**

Passenger Occupant Protection

Requires that lap belts are installed at every seating position

COMPARTMENTALIZATION

- **Buses Differ From Passenger Vehicles**

1. Larger - High Ground Clearance

2. Heavier - Lesser Crash Forces
   (Vehicle to Vehicle)

3. Structure - Different Crash Force Distribution

COMPARTMENTALIZATION PASSIVE PROTECTION

- Energy Absorbing Seat Back Structures
- Padded Seat Backs
- Strong, Closely Spaced Seats

OBJECTIVES

- Determine Effectiveness of Current Federal Requirements
- Identify Restraint Alternatives
- Identify Fatal Bus Crash Conditions

OBJECTIVES - Continued

- Develop a Sled Test Pulse (Crash Testing)
- Evaluate Performance of Restraint Alternatives (Sled Testing)

OBJECTIVES - Continued

- Estimate Overall Safety Performance of Restraint Alternatives
- Make Recommendations Based on Findings

PLANNED RESEARCH

- **PHASE I - Problem Definition**
  - Scope
  - Fatal Crash Environment
- **PHASE II - Sled Test Pulse Development**
- **PHASE III - Sled Testing and Validation**

PROBLEM DEFINITION

- **Literature Survey**
- **Data Base Analysis**
  - Sources:
    - FARS
    - GES
    - NASS
    - NTSB/SCI
- **Notice Issued Requesting Public Input**
- **State and Local Crash Information**

SCHOOL BUS INJURIES (GES)

- **Estimated 8,500 Injuries Per Year**
  - 7,285 (86 %) Minor
  - 885 (10 %) Moderate
  - 350 (4 %) Serious to Critical

SCHOOL BUS FATALITIES

- **Since 1988 There Have Been:**
  - **416,000** Fatal Traffic Crashes in the U.S.
  - **1,265** (0.3 %) Were School Bus Related
  - In Which **1,409** People Have Died

SCHOOL BUS FATALITIES

- **Of The 1,409 School Bus Related Fatalities:**
  - 64 % Were Occupants of Other Vehicles
  - 27 % Were Non-occupants (Pedestrians, Bicyclists, etc.)
  - 10% Were School Bus Occupants (2 % Driver - **8% Passenger**)

FARS DATA
(Fatality Analysis Reporting System)

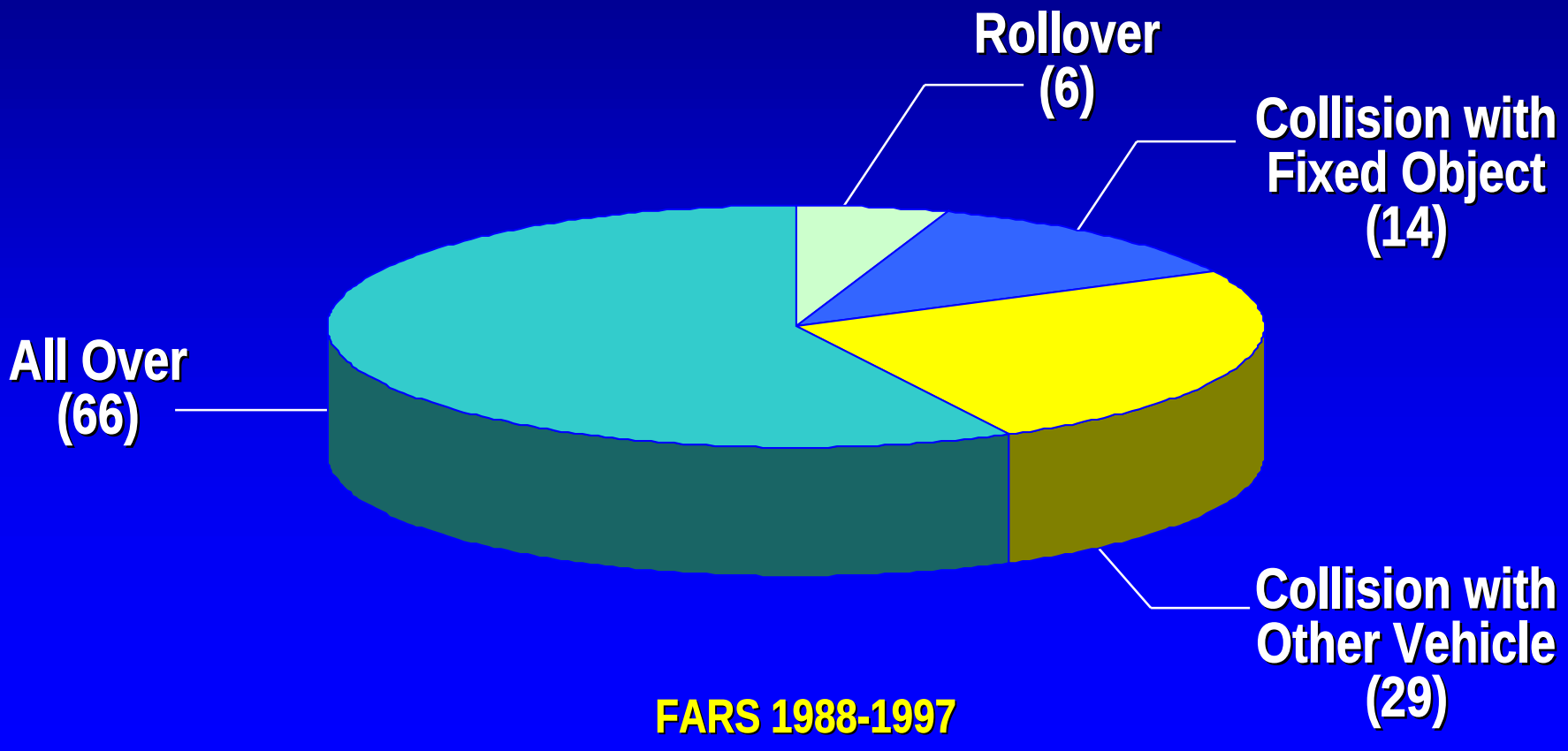
- **From 1988 to 1997**

  115 Passenger Fatalities in Large School Bus Crashes

SCHOOL BUS COLLISION ENVIRONMENT

Fatalities by Most Harmful Event

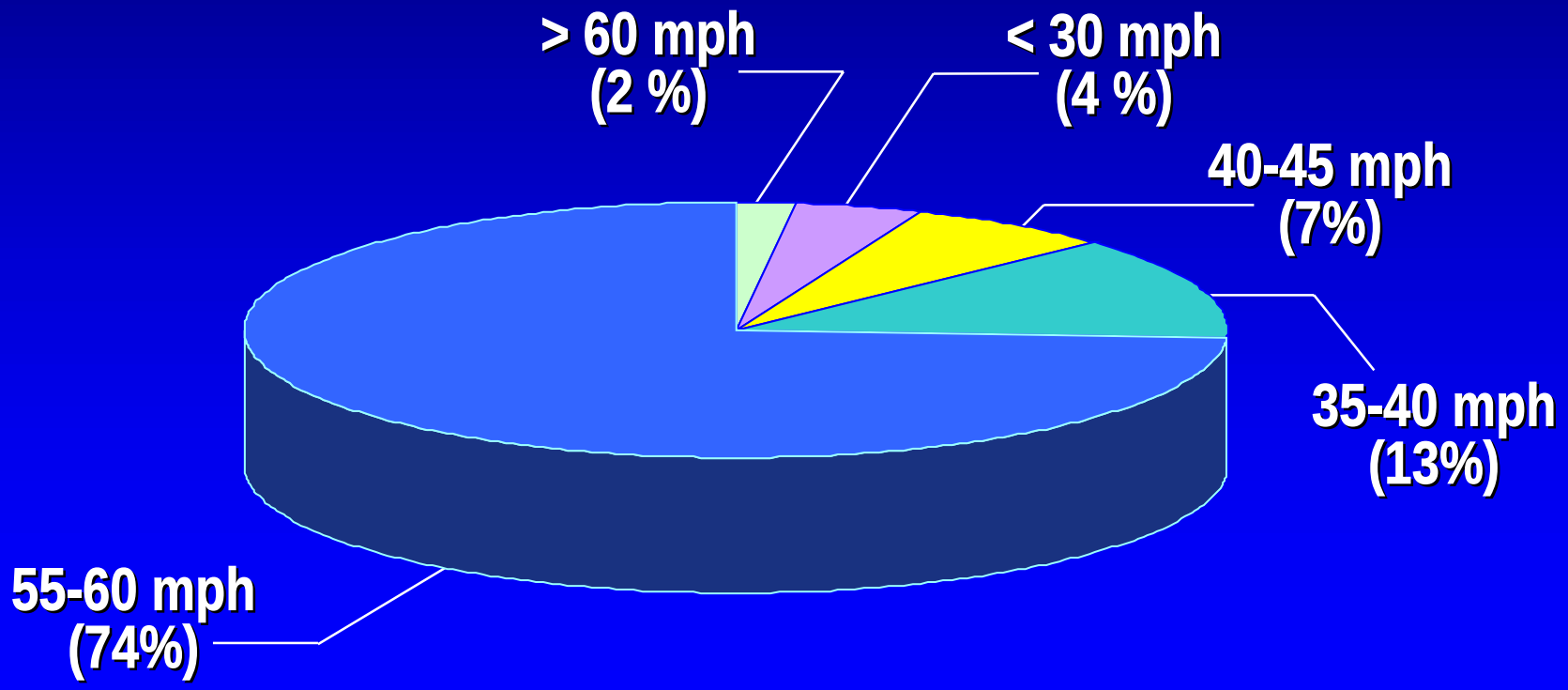
115 Total Fatalities



FARS 1988-1997

SCHOOL BUS COLLISION ENVIRONMENT

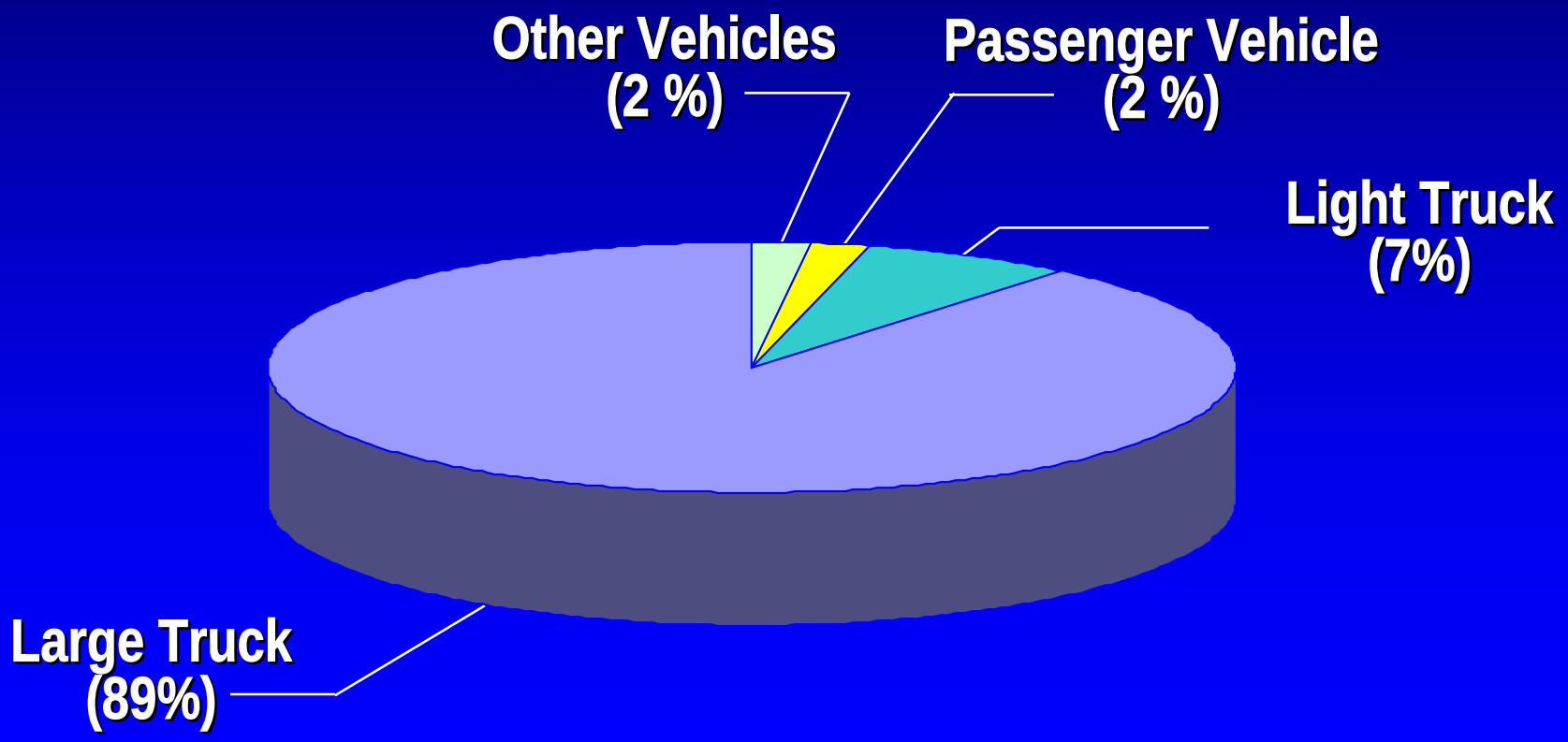
Fatalities In 2-Vehicle Crashes by Posted Speed Limit



FARS 1988-1997

SCHOOL BUS COLLISION ENVIRONMENT

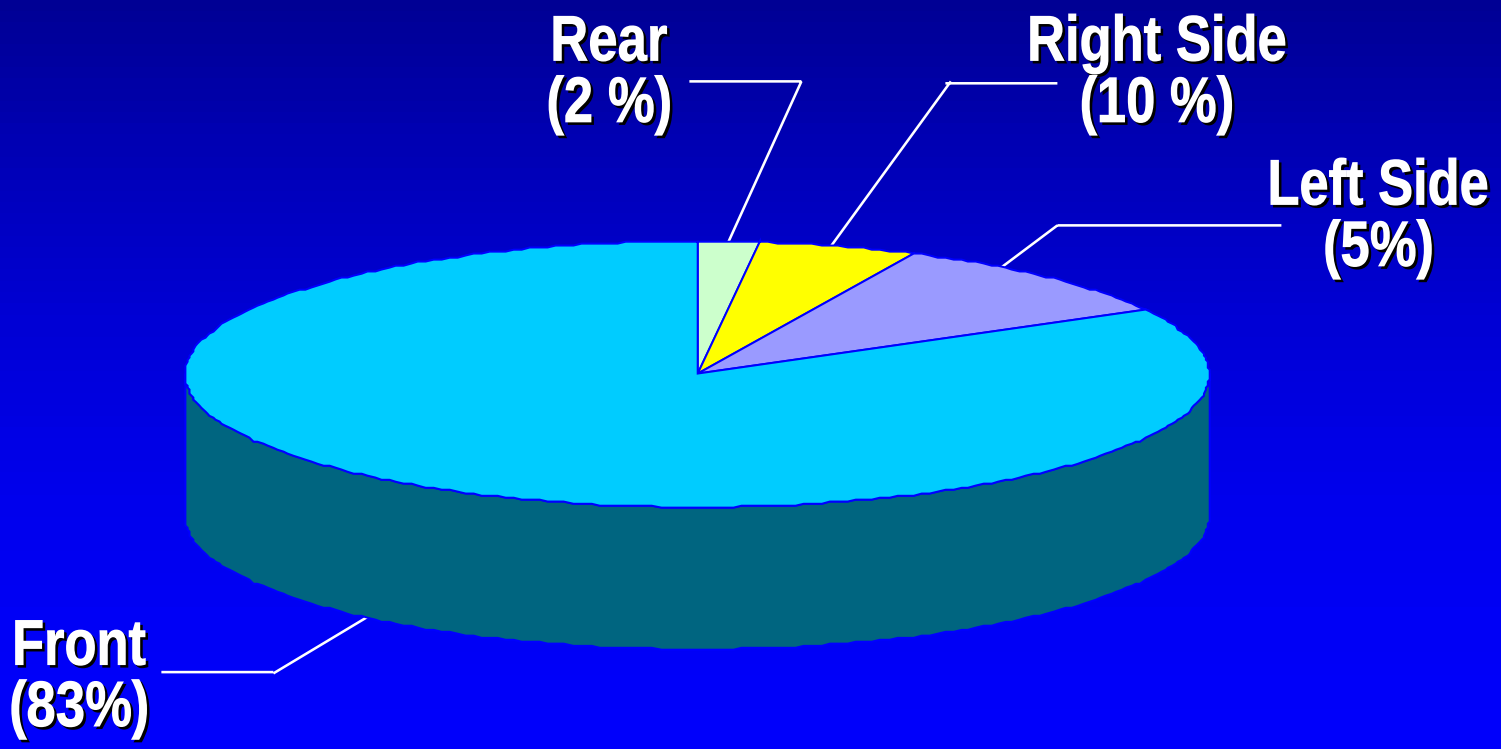
Fatalities In 2-Vehicle Crashes



FARS 1988-1997

SCHOOL BUS COLLISION ENVIRONMENT

Heavy Truck Impact Direction



FARS 1988-1997

PHASE I - SUMMARY

- **Low Probability of Fatal Injury**
  - 115 Fatalities (1988-1997)
- **Significant Factors, Fatal 2-Vehicle Crashes**
  - Posted Speed Limit 55-60 mph
  - Heavy Truck
    - Frontal Impact (83%)
    - Side Impact (15%)

PLANNED RESEARCH

- **PHASE I - Problem Definition**
  - Scope
  - Fatal Crash Environment
- **PHASE II - Sled Test Pulse Development**
- **PHASE III - Sled Testing and Validation**

PHASE II CRASH ENVIRONMENT DEFINITION

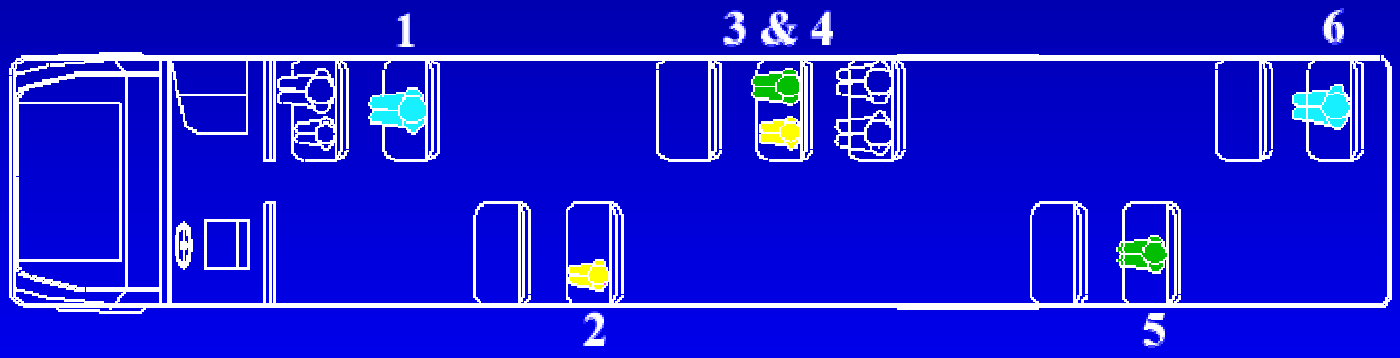
- Based on Phase I Results
- Representative of Real World Crash Environment
- Two Crash Tests Were Conducted

LABORATORY CRASH TESTS

- Frontal Rigid Barrier, 0^0, 30 mph
- Side Impact by Heavy Truck, 90^0, 45 mph

FRONTAL SEATING

BARRIER



HYBRID III 50th MALE

HYBRID III 5th FEMALE (12 Year Old)

HYBRID III 6 YEAR OLD

FRONTAL RIGID BARRIER

FRONTAL CRASH TEST RESULTS

DUMMY	Nij	HIC	CHEST G
1 (50th)	0.91	244	26.0
2 (6 Y/O)	1.57	93	30.8
3 (6 Y/O)	1.06	251	30.9
4 (5th FEM)	1.15	105	No Data
5 (5th FEM)	1.38	330	22.6
6 (50th)	0.84	150	22.3

FRONTAL CRASH TEST

- 30 mph Rigid Barrier Crash Test
- Type C Full Sized Conventional School Bus

Pre-Test

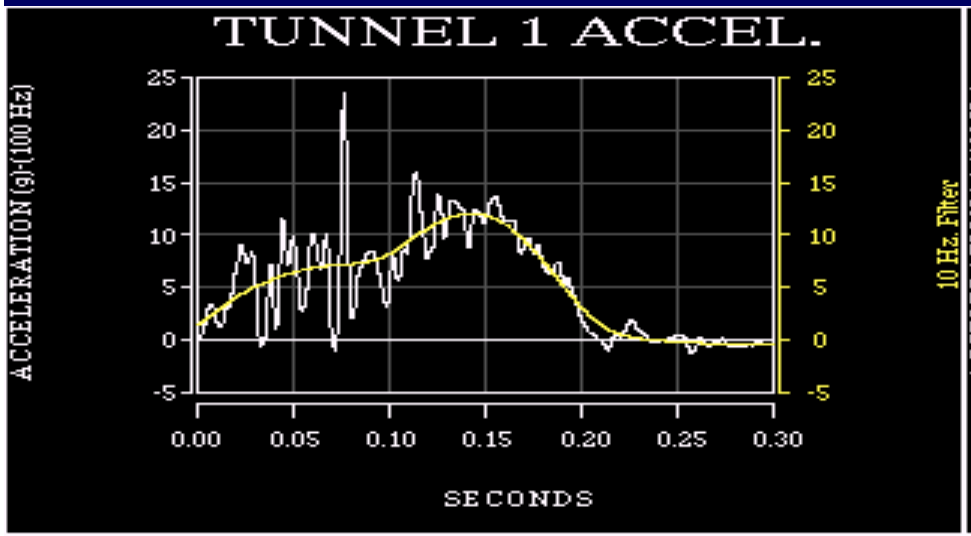
Post-Test

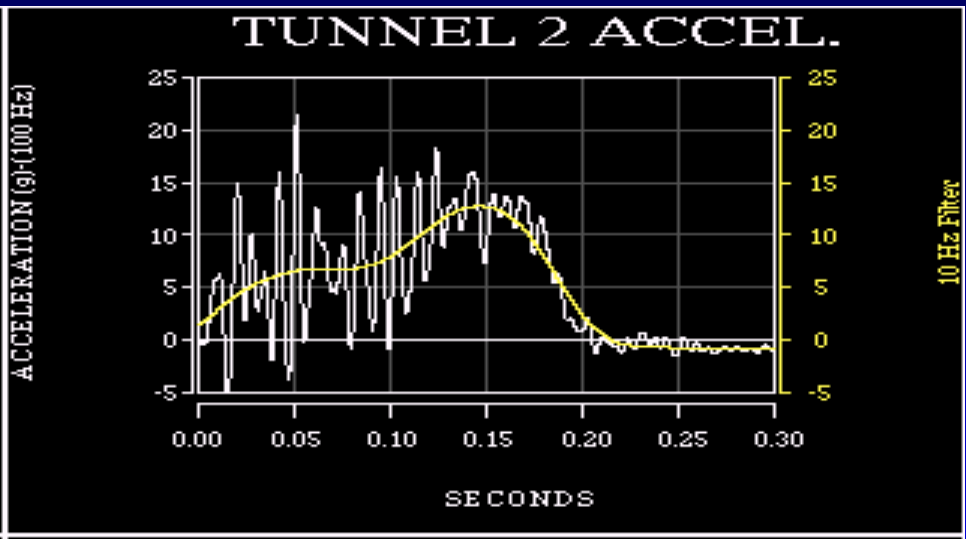
STATIC CRUSH DATA

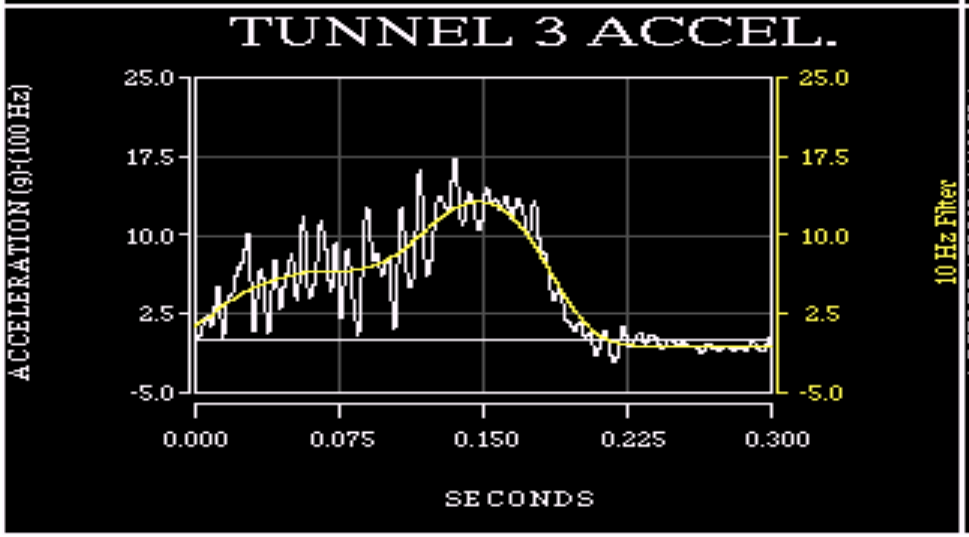
- Maximum Static Frame Crush - 8.1 inches
- Average Static Frame Crush - 4.5 inches
- Significant Body Crush But Little Frame Crush

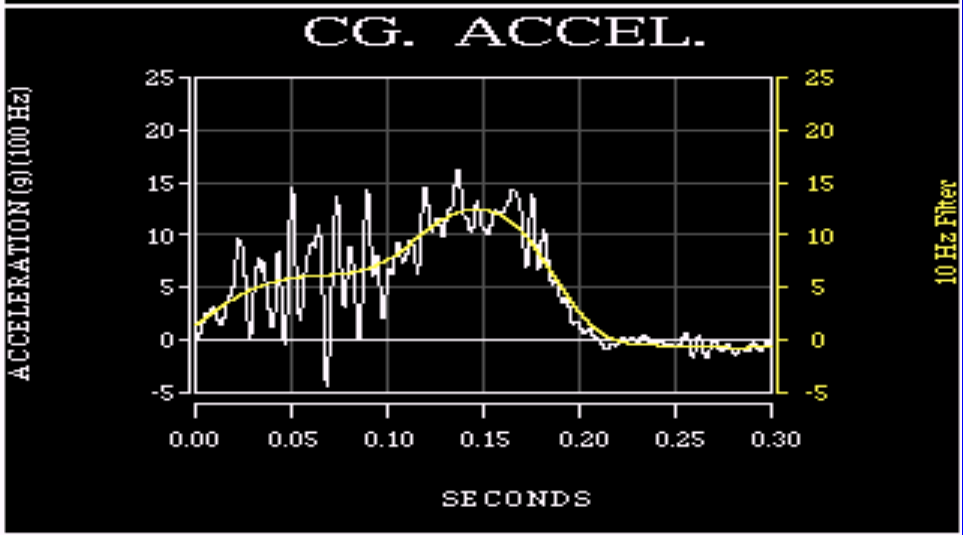
FRONTAL CRASH TEST
Motion of Body Relative to Frame

FRONTAL CRASH TEST DECELERATION PULSE

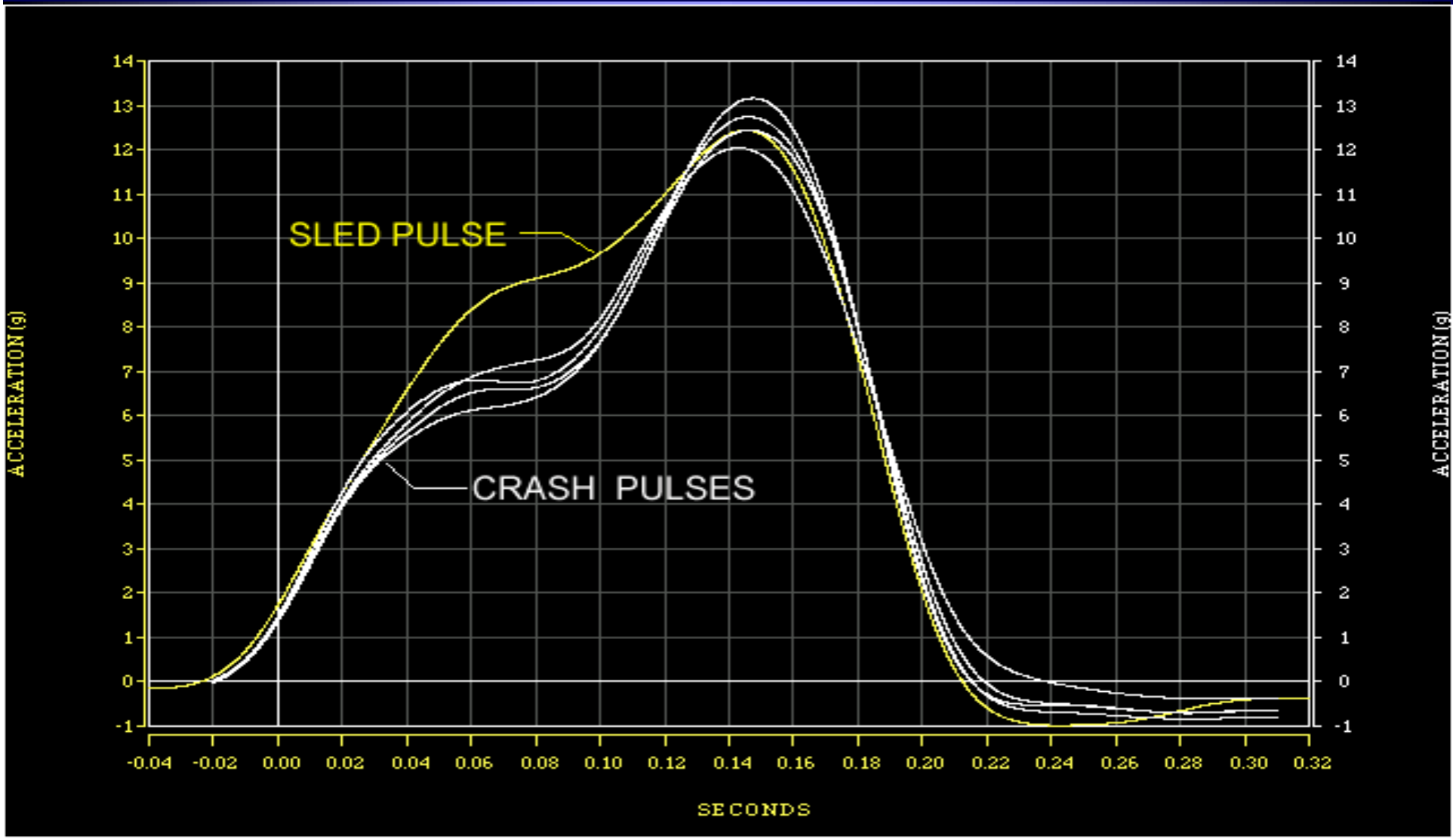








ACCELERATION PULSES
Filtered to 10 Hz



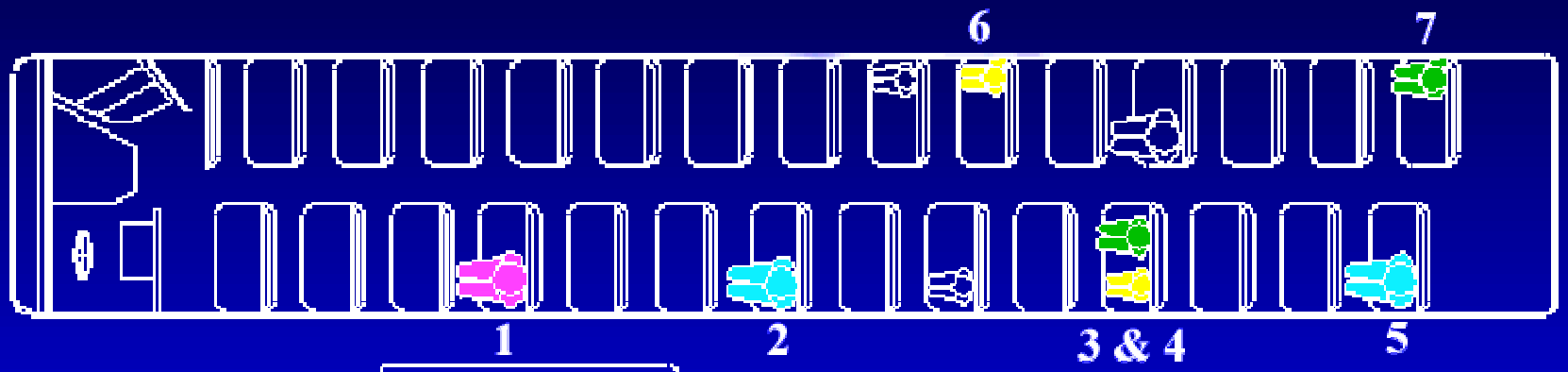
SCHOOL BUS LABORATORY CRASH TESTS

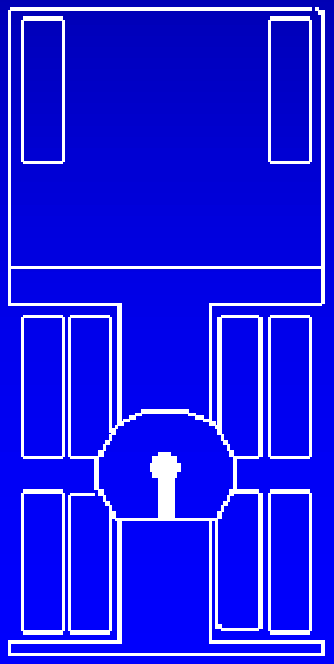
- Frontal Rigid Barrier, 0^0, 30 mph
- Side Impact by Heavy Truck, 90^0, 45 mph

SIDE IMPACT CRASH TEST

- Type D Transit Style (Rear Engine)

SIDE IMPACT POSITIONING





- SID 50th MALE
- HYBRID III 5th FEMALE - (12 Y/O)
- HYBRID III 6 YEAR OLD
- HYBRID II 50th MALE

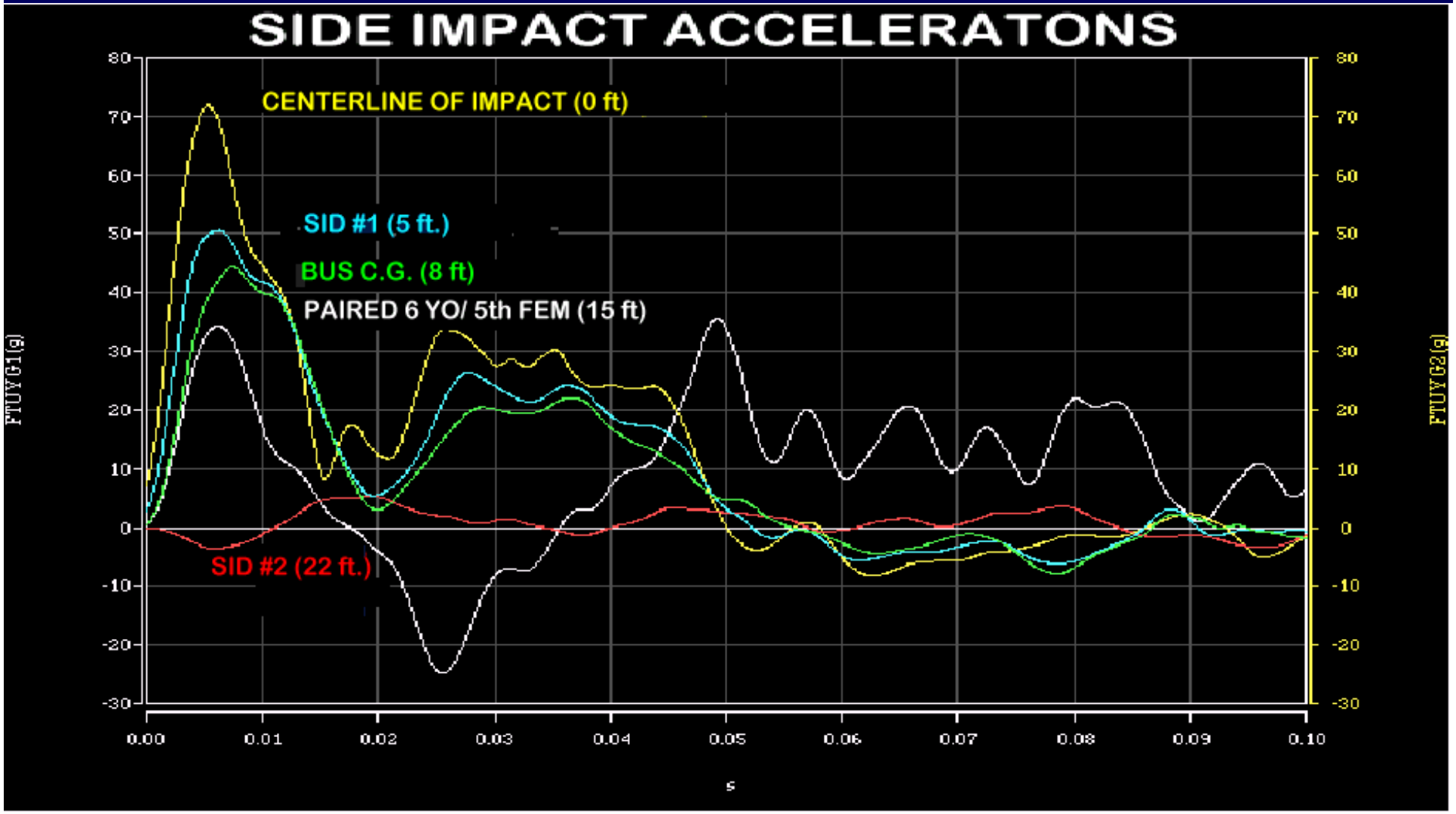
SIDE IMPACT CRASH TEST

SIDE IMPACT CRASH TEST

SIDE IMPACT TEST RESULTS

DUMMY	HIC	CHEST G	TTI
1 (HII)	2164		
2 (SID)	277		54.7
3 (5th)	85	27.7	
4 (6 Y/O)	124	11.1	
5 (SID)	133		7.1
6 (6 Y/O)	54	22.7	
7 (5th)	1	7.4	

SIDE IMPACT RESULTS



SIDE IMPACT RESULTS

- **Point of Impact**
  - Unsurvivable
- **Outside Impact Zone**
  - High Probability of Survival
  - Low Probability of Serious Injury

PLANNED RESEARCH

- **PHASE I - Problem Definition**
  - Scope
  - Fatal Crash Environment
- **PHASE II - Sled Test Pulse Development**
- **PHASE III - Sled Testing and Validation**

PHASE III
Testing and Validation

- Fabricate Sled Buck
- Develop Test Matrix
- Analyze Results

FABRICATE SLED BUCK

FRONTAL SLED BUCK

SCHOOL BUS SLED TEST

FRONTAL SLED TEST BASELINE CONFIGURATION

PHASE III
Testing and Validation

- Fabricate Sled Buck
- Develop Test Matrix
- Analyze Results

SLED TEST MATRIX

- 3 Occupant Sizes
- 3 Restraint Strategies
- 3 Loading Conditions

OCCUPANT SIZES

- 6 Year Old Hybrid III (44.9 in /51.6 lbs) Typical Young Child
- 5th Female Hybrid III (59.1 in/108.0 lbs) Size of an Average 12 Year Old
- 50th Male Hybrid III (69 in/172.3 lbs) Representative of a Large High School Student

SLED TEST CONDITIONS

- 3 Occupant Sizes
- 3 Restraint Strategies
- 3 Loading Conditions

RESTRAINT STRATEGIES

- **Compartmentalization**
  - (Seat Spacing = 19 inches)
- **Lap Belt Only**
- **Lap/Shoulder Belt - With Modified Seat Back**

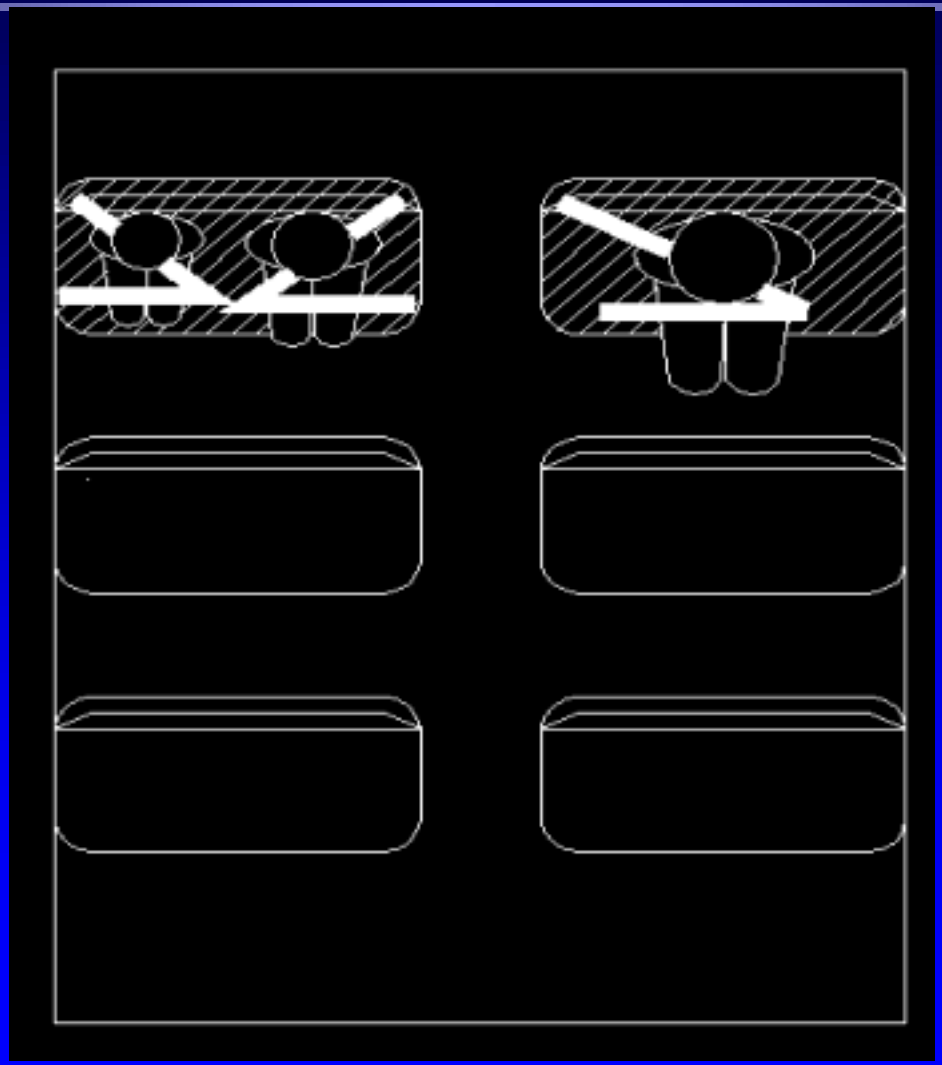
SLED TEST CONDITIONS

- 3 Occupant Sizes
- 3 Restraint Strategies
- 3 Loading Conditions

LOADING CONDITIONS

- Restrained Without Rear Loading
- Restrained With Rear Loading From Unrestrained Occupants
- Unrestrained Occupant Into Seat Back

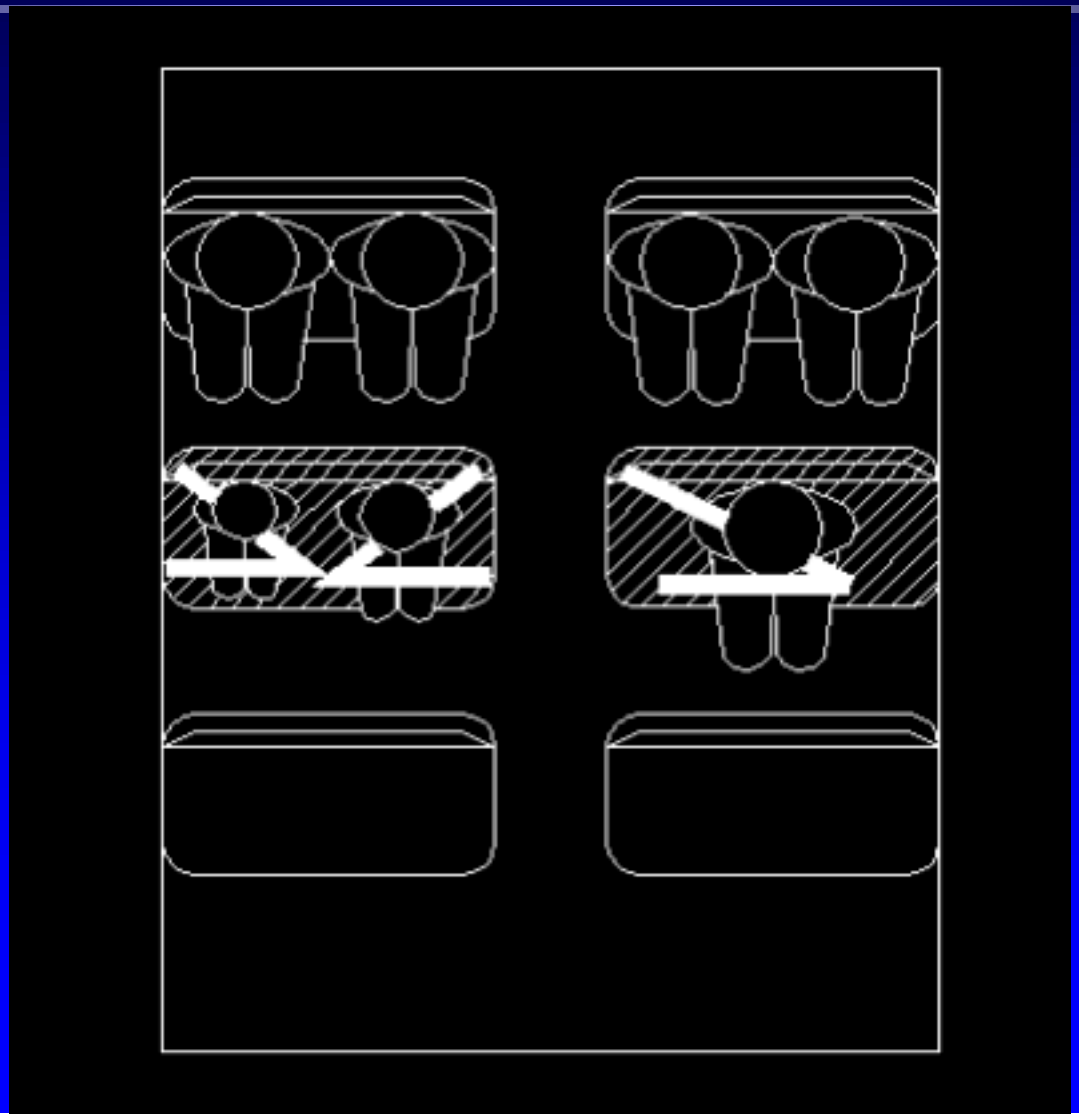
RESTRAINED
Without Rear Loading



LOADING CONDITIONS

- Restraint Without Rear Loading
- **Restraint With Rear Loading From Unrestrained Occupants**
- Unrestrained Occupant Into Seat Back

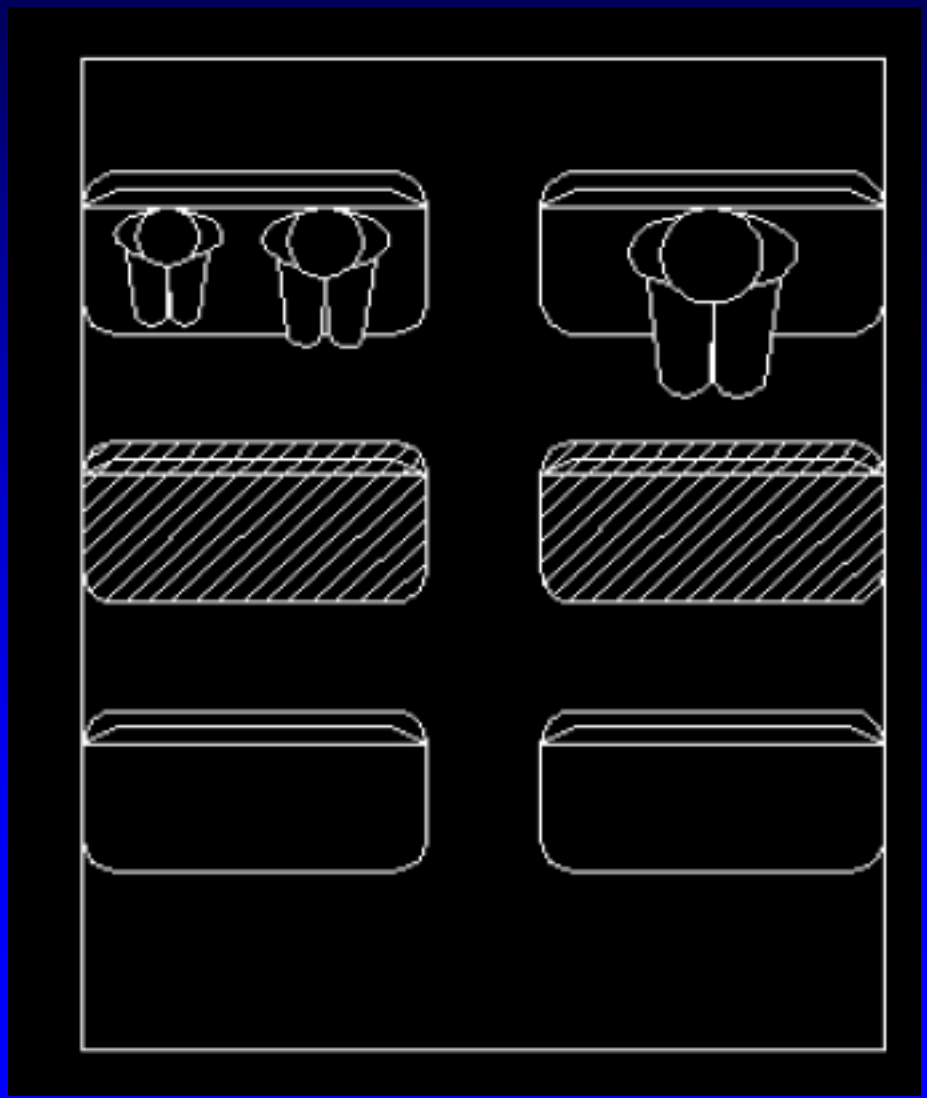
RESTRAINED
With Rear Loading



LOADING CONDITIONS

- Restraint Without Rear Loading
- Restraint With Rear Loading From Unrestrained Occupants
- Unrestrained Occupant Into Seat Back

UNRESTRAINED INTO SEAT BACK



PHASE III
Testing and Validation

- Fabricate Sled Buck
- Develop Test Matrix
- Analyze Results

PRELIMINARY SLED TEST RESULTS

- **Compartmentalization**
  - Overall Performed Well
    - Some Nij Values Exceed Injury Reference
  - Worked Best for Smaller Occupants
    - Larger Occupants Tend to Override Standard Height Seat Back

PRELIMINARY SLED TEST RESULTS

- **Lap Belt**
  - Overall Slightly Higher Nij Values Than Compartmentalization
  - Nij Values May Be Sensitive to Seat Spacing
  - Prevents Larger Occupants From Overriding Seat Back

PRELIMINARY SLED TEST RESULTS

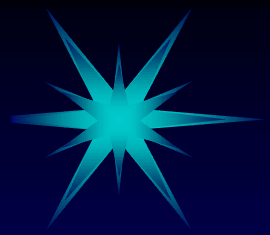
- **Lap/Shoulder Belt**
  - Best Overall Performer When Properly Worn
  - Resulting Stiffer Seat Backs May Cause Higher Injury Values for the Unrestrained or Improperly Restrained Occupant
  - Prevents Larger Occupants From Overriding Seat Back

SIDE IMPACT MITIGATION CONCEPTS

- Effects of Lap Belt and Lap/Shoulder Belt
- Seat Back and Seat Bench Contouring
- Side Wall Padding/Design

FUTURE WORK

- **Continue Frontal Protection Evaluation**
  - Seat Spacing
  - Other Crash Severities
  - Seat Back Design
  - Other Restraint Concepts
- **Conduct Testing in Other Crash Modes**
  - Side Impact
  - Rollover?



THE END